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Principal Author:
LTC Darryl Ahner

Other Author(s):

Principal Author's Organization:
U.S. Army TRADOC Analysis Center

Complete mailing address:
TRADOC Analysis Center - Monterey
Naval Postgraduate School
P. O. Box 8695
Monterey, CA 93943

X [signature]
Principal Author's Signature: Date: 2 MAY 2008
Phone: (831) 656-7574
FAX: (831) 656-3084
Email: darryl.ahner@us.army.mil

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X [signature]
Releasing Official's Signature:

Printed name: Leroy Jackson

Organization: TRAC - Monterey

Date: 2 May 2008

Complete mailing address:
TRADOC Analysis Center - Monterey
Naval Postgraduate School
P. O. Box 8695
Monterey, CA 93943

Phone: (831) 656-3087
FAX: (831) 656-3084

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Modeling Uncertainty from Sensors to Decision Makers

LTC Darryl Ahner, Dr. Tom Anderson, MAJ Mike Martin

Briefing for: MORSS 2008

June 2008

Purpose and Agenda

Purpose: To share information on the TRAC-MTRY led representation of uncertainty within combat models research. This research includes representation of uncertainty from false positive targets and sensor errors.

Agenda:

- JDL Data Fusion Model.
- False Positives.
  - Research Objectives.
  - Definition.
  - Technical Approach.
  - Summary.
- Sensor Errors.
  - Research Objectives.

Joint Directors of Laboratories (JDL) Data Fusion Model

Level 1: Correlation and tracking estimation of unit position, velocity, type, ID.

*** Only level addressed further here.**

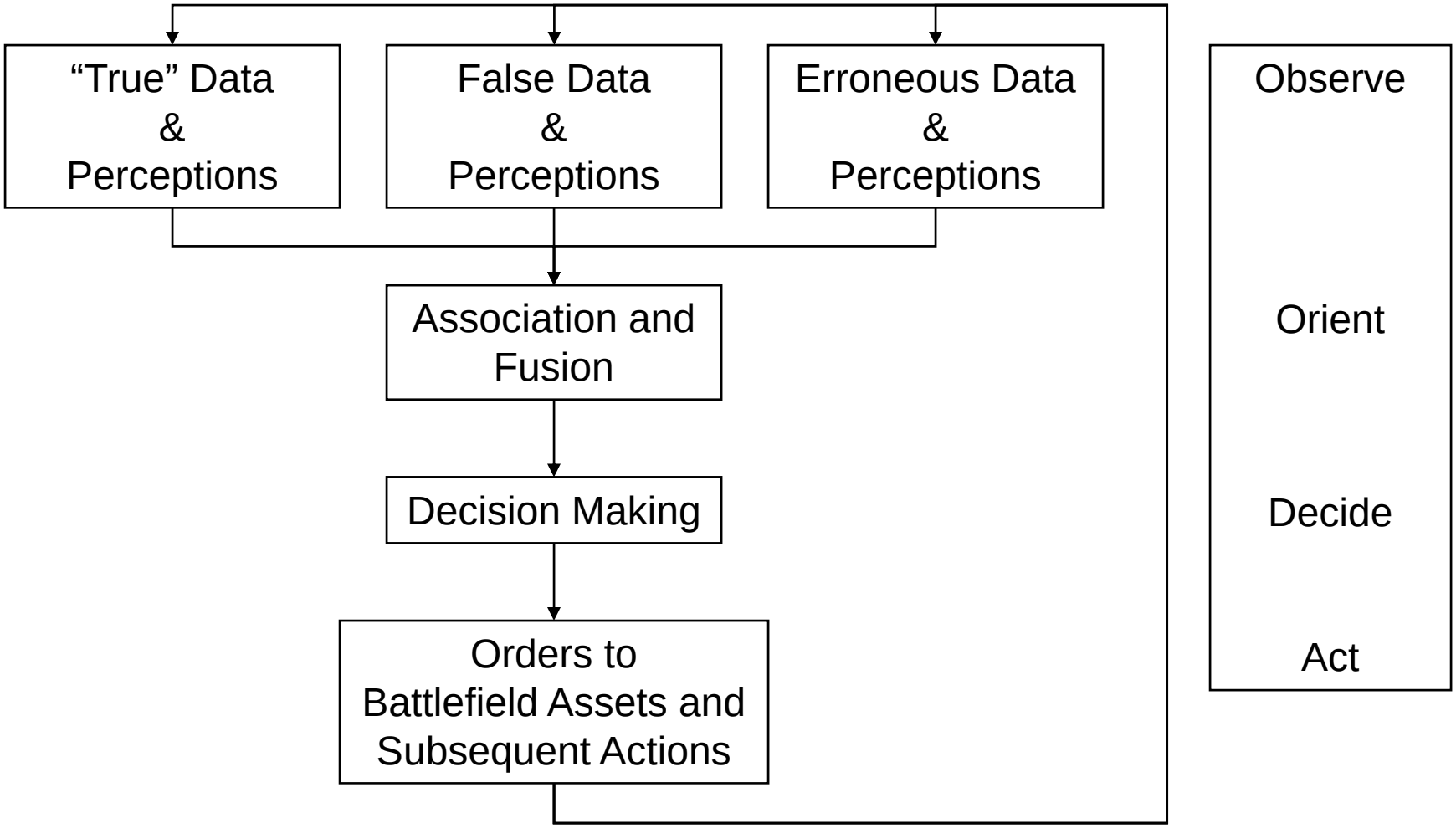
Level 2: Situation assessment.

Level 3: Threat assessment.

Level 4: Process monitoring and optimization.

Level 5: Human computer interaction.

Types of Data in Level 1 Fusion



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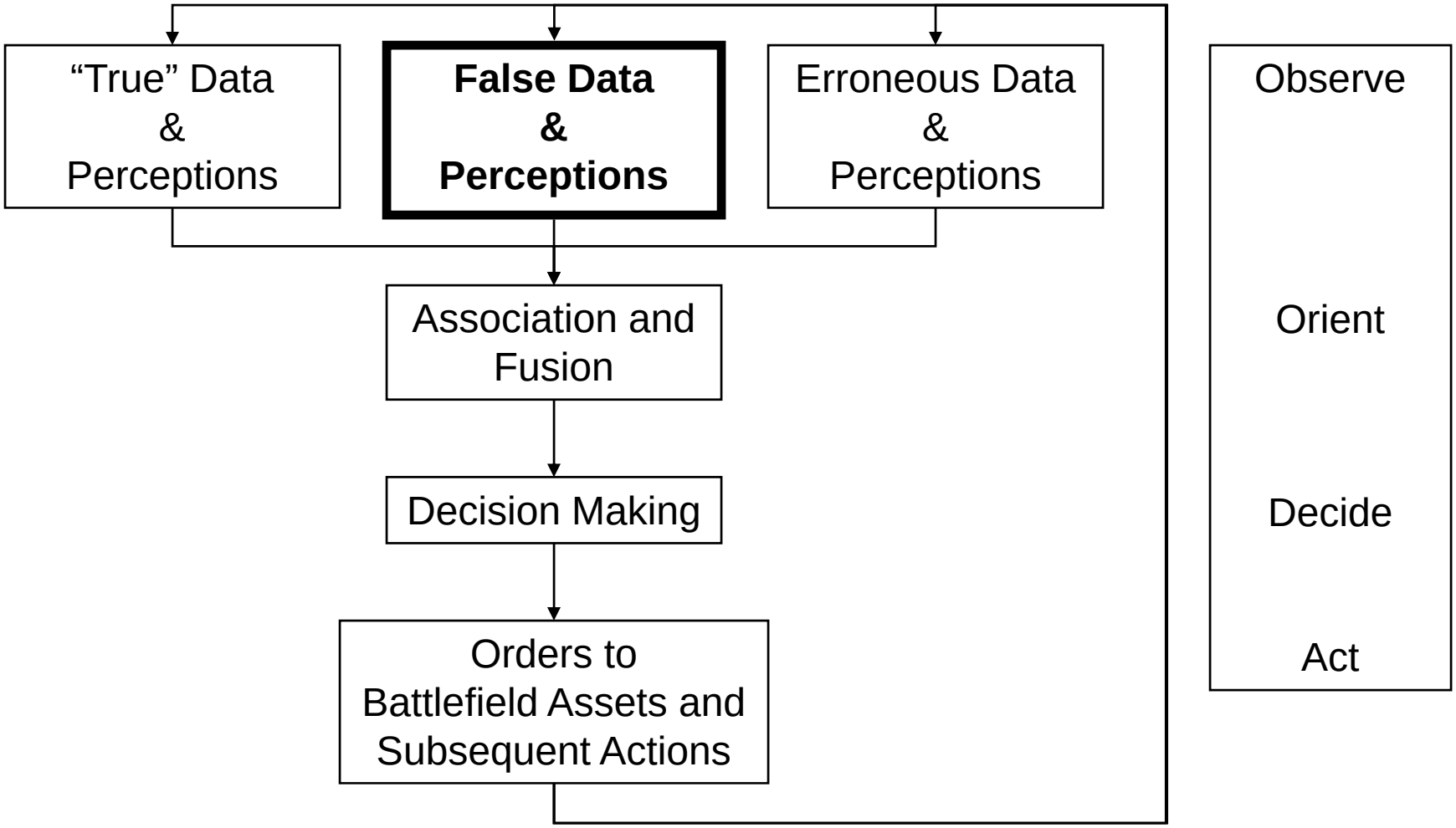


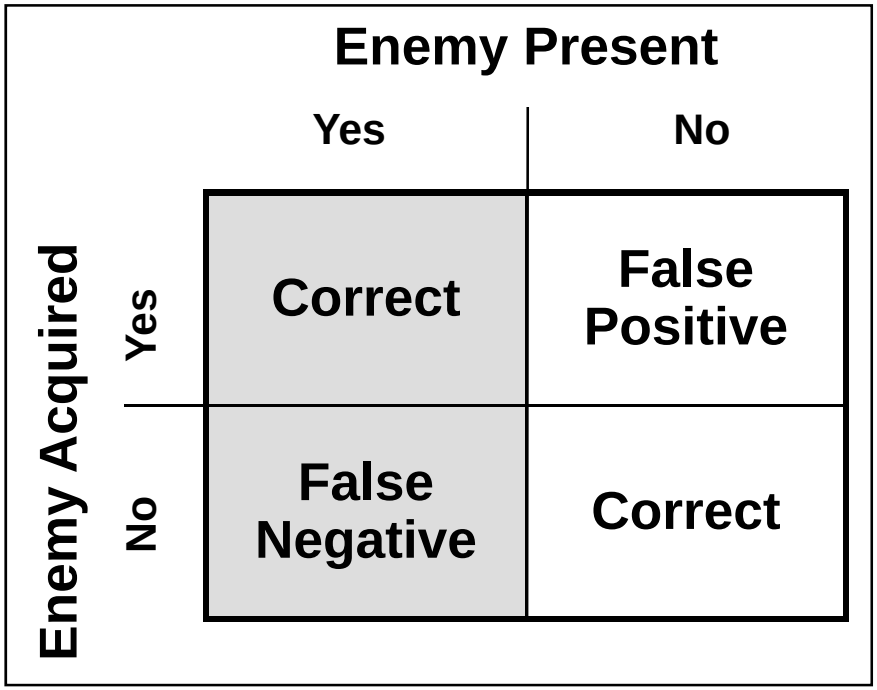
False Positive Research Objectives

- **Collect necessary data, through research and experimentation, to characterize the probability of false acquisitions in varying conditions.**
- **Develop models and methodologies to implement “false positive” acquisitions within target simulations, therefore improving the representation of information ambiguity.**
- **Create software to implement stand alone model and components for use within JDAFS and/or COMBAT XXI.**

“False Positive Acquisition” Definition

- Permitting the possibility of false positive target acquisitions will inject ambiguity into simulated situational awareness (no longer can you have absolute confidence in own SA).
- This is distinct from misidentification or misclassification, where an entity perceives incorrect information from an existing entity. In a False Positive acquisition, there is no other entity, regardless of ‘side’.
- Redundant observation coverage becomes meaningful, and actions may be taken to “confirm or deny” SA.

Possible Acquisition Outcomes

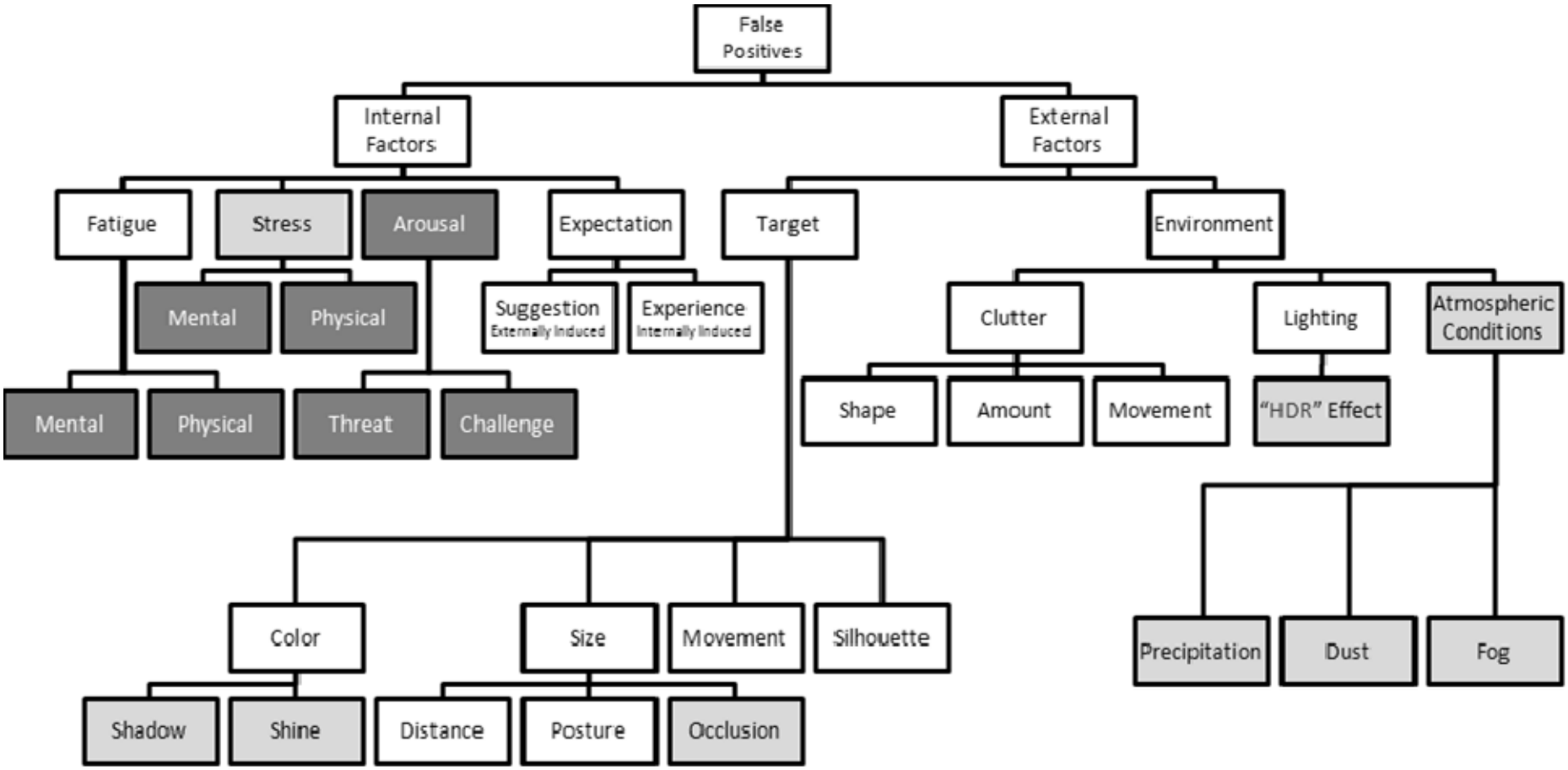


- Simulations solely relying upon ACQUIRE implicitly neglect all acquisitions on the right side of the above chart, as ACQUIRE calculation requires both an observer and a target.

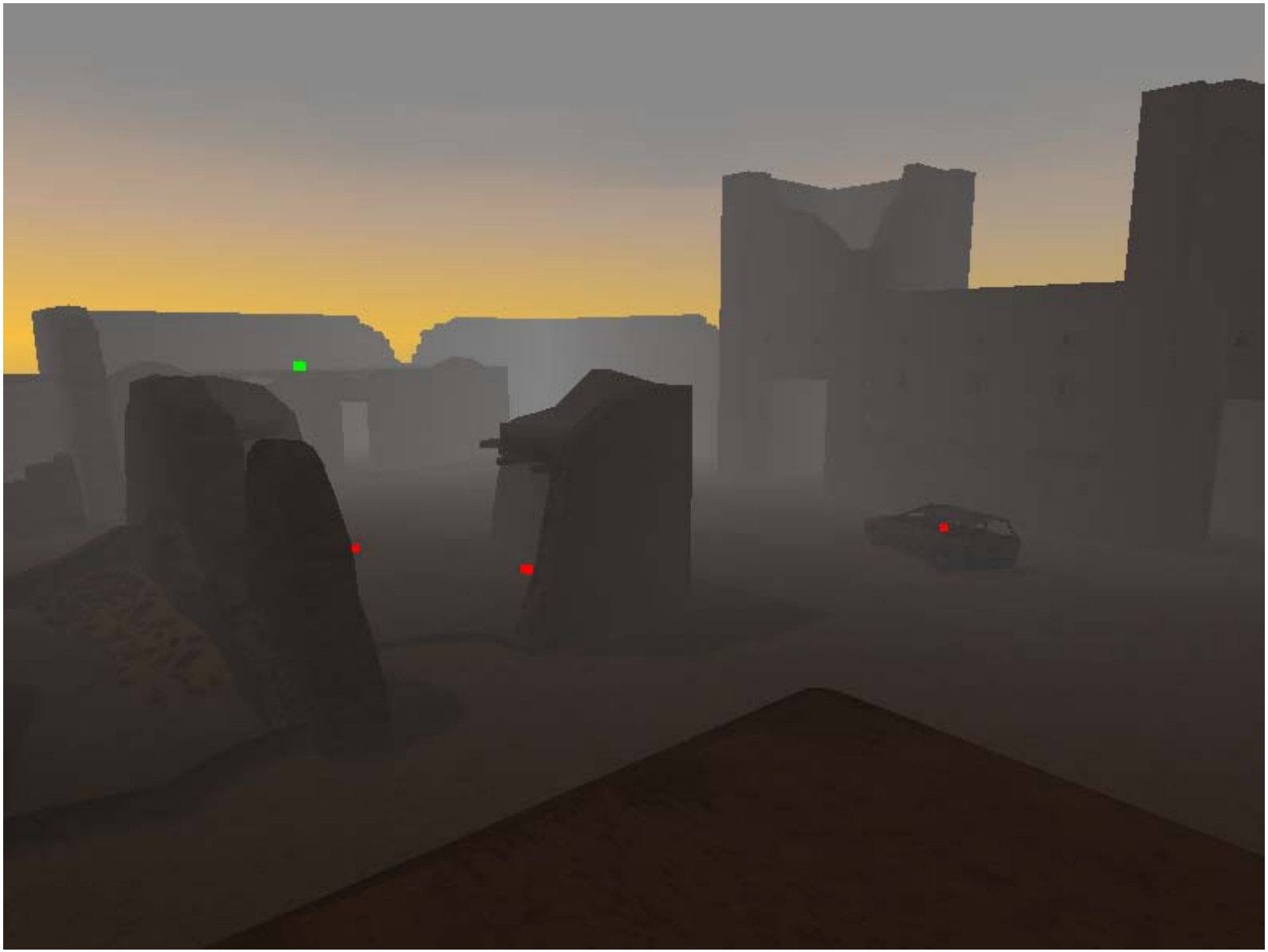
False Positive Technical Approach

- **Develop and conduct appropriate experiments to capture additional data concerning False Positive acquisitions.**
- **Develop models, based on experimentation results.**
  - **Basic experimental framework previously used in a series of experiments conducted in the MOVES Institute at the Naval Postgraduate School.**
  - **Experiments focused comparing experimental human performance at target detection with probability of detection as determined by ACQUIRE and alternative target acquisition models.**
  - **During experiment design, slides not depicting a target were inserted as controls. Experiments registered false positive target acquisitions on these slides.**
  - **Experiment design being restructured to capture significant data relating to false positives.**
- **Develop software to implement model.**

Initial Factor Decomposition



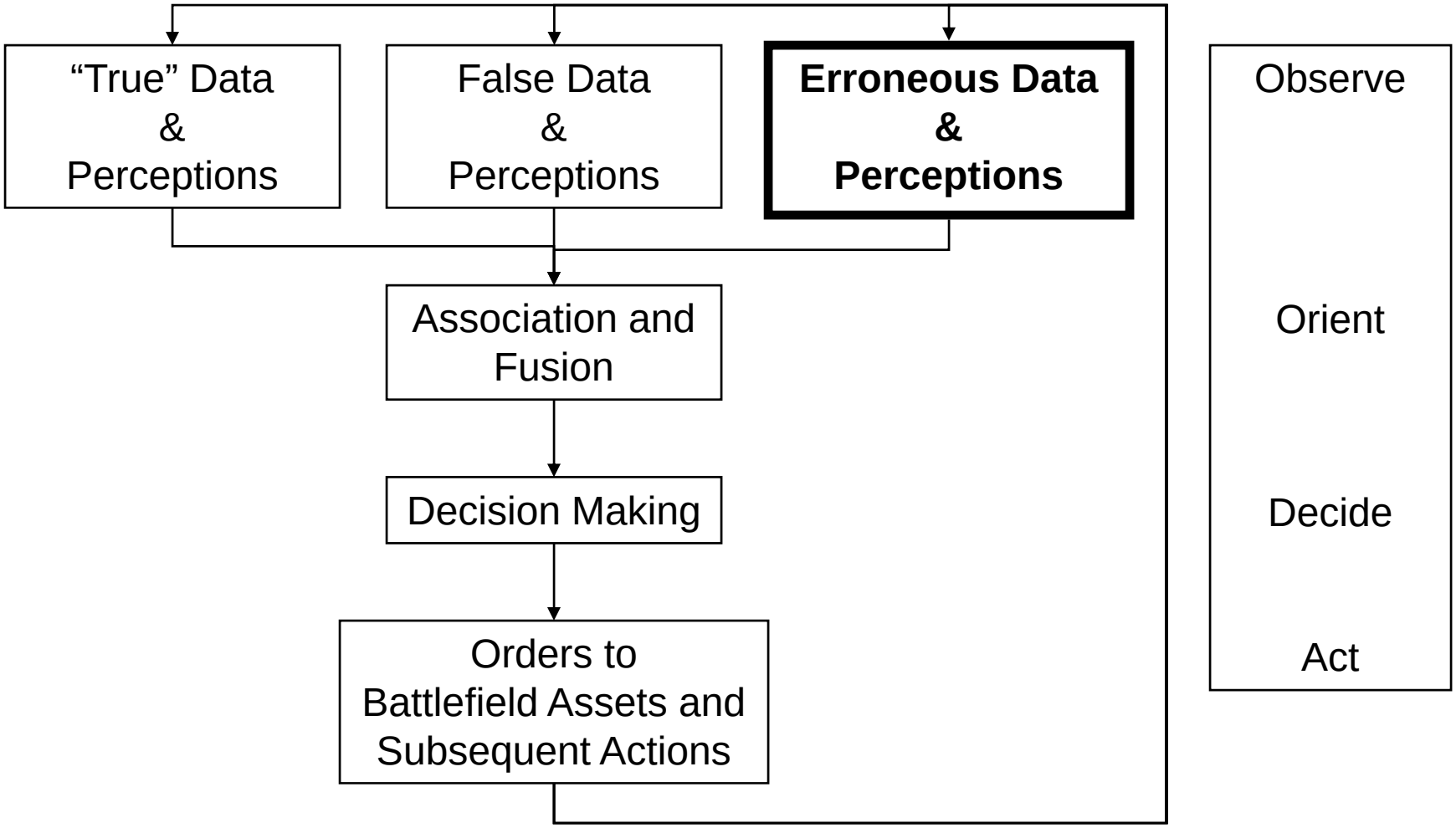
Example of March 08 Experiment



False Positive Summary

- **Most significant factor affecting rate of “false positives” is measurement of vertical edges.**
- **Developed a hierarchical decomposition of false positive perceptions and an associated list of contributing factors.**
- **Leveraging previous work at Naval Postgraduate School to shape the human performance experimentation.**
- **Developing a model that will produce a distribution and characterization of false positive perceptions based on the provided inputs.**
- **Experimentation will also capture data that can analyze subject search patterns for simulation representation.**
- **Developed a versatile research tools and capabilities that can be utilized to support future perception and information research.**

Types of Data in Level 1 Fusion



Ambiguity of Sensor Detection Research Objectives

- **We seek to introduce ambiguities in data association into modeling and simulation (tactical-level). We seek to increase the fidelity of situational awareness representation by more accurately representing uncertainty in modeling association, fusion, and BDA.**
- **Goals for this project:**
  - **Create a flexible descriptive model that realistically accounts for inaccurate / uncertain identification / classification / affiliation of acquired entities and accounts for imperfect association of this information (association model).**
  - **Create new BDA representations that better account for uncertain inputs such as false positives and sensor error.**
  - **Provide probability confusion matrix, for vehicles, for not only misidentification but misrecognize and misclassify.**
  - **Provide elliptical error probablilities for sensor target location errors, capturing the asymmetry of sensor TLEs in range and azimuth.**

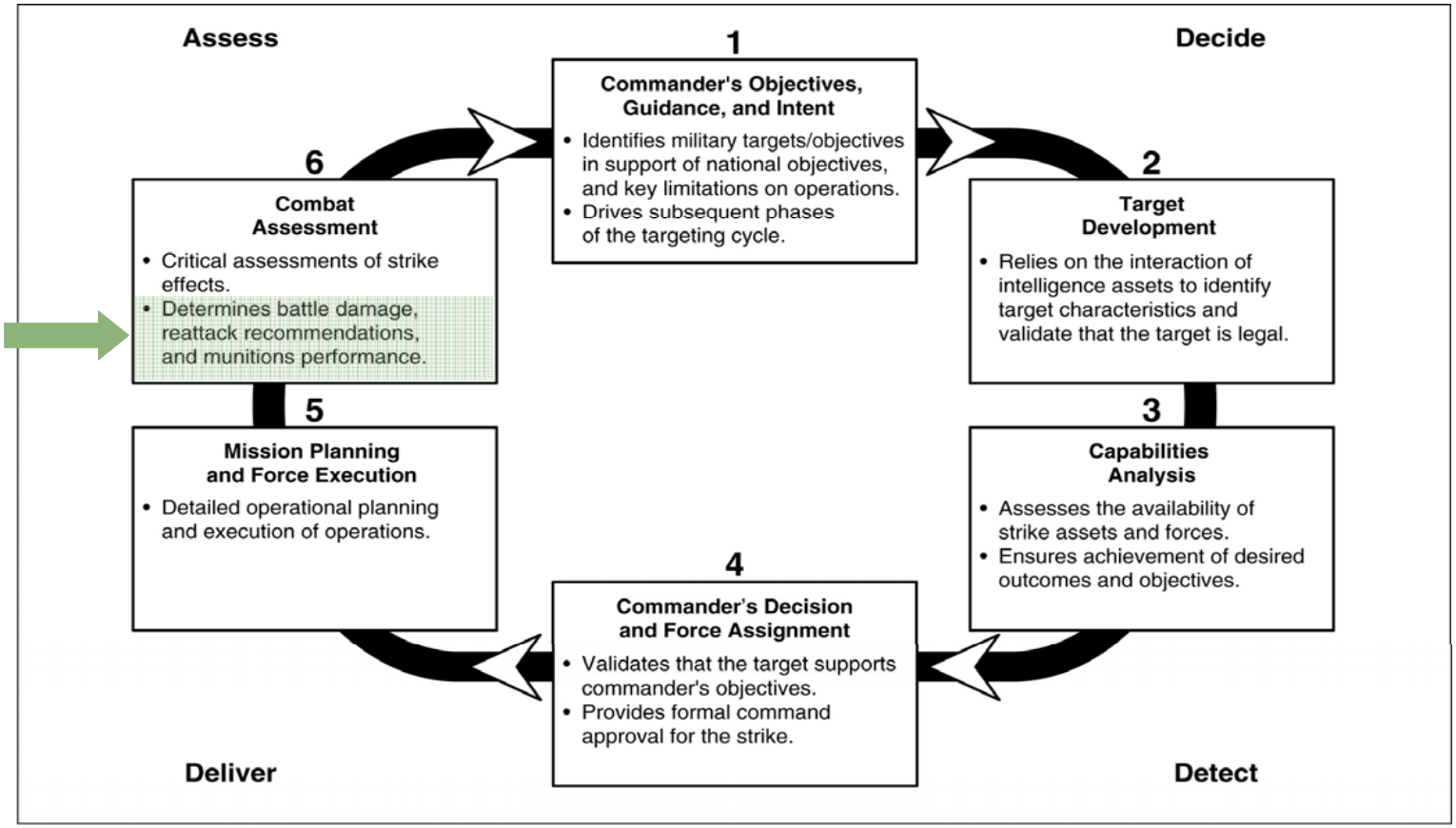
Technical Approach

The hard part of multiple target tracking is associating measurements with targets. Current model knowledge structures do not adequately account for associating ambiguity:

- **Association algorithms are needed to account for directional and range uncertainty of sensors in addition to time delays and decays associated with sensed position information. Currently looking to expand Maneuvering Target Statistical Tracker (MTST).**
- **Identification errors and false detects are not accounted for in current fusion / decision algorithms.**
- **Fusion algorithms such as the Kalman filter adequately provide fusion for information association models, however, these filters assume well-defined association algorithms.**
- **Most current computer generated force (CGF) based simulation models, which tend to include behavior models that perform automated decision making, rely on the AMSAA heuristic for BDA modeling and do not adequately represent current BDA doctrine / TTP and associated commander decisions.**

Prototype, proof-of-concept implementation will use the Joint Dynamic Allocation of Fires and Sensors (JDAFS/DAFS) simulation that forms the basis for an API into CombatXXI.

BDA in the Combat Assessment Process



Source: DOD.

- Perceived BDA is one of the most complex and uncertain processes facing the soldier in live combat.
- Modeling and simulation community has yet to adequately model the perceived BDA process in combat models.

Common Battle Damage Assessment (BDA) Description

Three possibilities of BDA entity description:

1. No Information.
2. No damage.
3. Damage specified by kill type.
   - (F) Firepower.
   - (M) Mobility.
   - (MF) Mobility and firepower.
   - (K) Catastrophic.

By Entity Type:

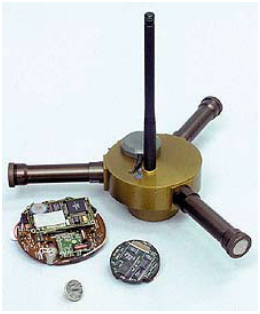
- Vehicles (F, M, MF, or K).
- Infantry (only K).

Improving BDA Methodology

- Generate and execute WEB Survey with NPS OR students with *prior experience* in BDA.
- *Empirically* determine probabilities for the conditional distributions of events for each given kill state.
- Implement results in JDAFS.
- Handoff results to TRAC-WSMR for Combat-XXI.

Summary

- **Result is a flexible descriptive model that realistically accounts for inaccurate / uncertain identification / classification / affiliation of acquired entities and accounts for imperfect association of this information (association model).**
- **Result is an expanded model that better accounts for uncertainty.**
- **Implementation will be a prototype, proof-of-concept implementation using the Joint Dynamic Allocation of Fires and Sensors (JDAFS/DAFS) simulation that forms the basis for an API that may be used by COMBAT XXI .**



Questions

Point of contact is

Dr. Tom Anderson
TRAC-Monterey ERDC liason
thomas.anderson5@us.army.mil
Phone 831-656-2977
DSN 756-2977